

Claims

What is claimed is:

1. An apparatus for measuring at least one parameter of a process flow flowing within a pipe, the apparatus comprising:
 - at least two pressure sensors clamped onto the outer surface of the pipe at different axial locations along the pipe, each of the pressure sensors providing a respective pressure signal indicative of a pressure disturbance within the pipe at a corresponding axial position, each of the pressure sensors comprising a piezoelectric film sensor; and
 - a signal processor , responsive to said pressure signals, which provides a signal indicative of at least one parameter of the process flow flowing within the pipe.
2. The apparatus of claim 1, wherein each of the pressure sensors further include a strap for attaching the piezoelectric film sensor thereto.
3. The apparatus of claim 1, wherein the process flow is one of a single phase fluid and a multi-phase mixture.
4. The apparatus of claim 2, wherein the piezoelectric film sensor is attached to the outer surface of the strap and/or the inner surface of the strap.
5. The apparatus of claim 2, wherein the strap is a metallic material.
6. The apparatus of claim 2, further includes a clamping device for attaching the ends of one of the pressure sensors to clamp the pressure sensor onto the pipe.
7. The apparatus of claim 2, wherein the pressure sensors are removably clamped to the pipe.
8. The apparatus of claim 2, wherein the pressure sensors are permanently clamped to the pipe.

9. The apparatus of claim 1, wherein the piezoelectric film sensor includes at least one of polyvinylchlorine fluoride (PDVF), polymer film and flexible PZT.
- 5 10. The apparatus of claim 1, wherein the piezoelectric film includes a pair of conductors disposed on opposing surfaces of the piezoelectric-film.
11. The apparatus of claim 10, wherein each the pair of conductors is a coating of silver ink.
- 10 12. The apparatus of claim 1, wherein the piezoelectric film extends around a substantial portion of the circumference of the pipe.
13. The apparatus of claim 1, wherein the piezoelectric film has a thickness greater than 8 mm.
- 15 14. The apparatus of claim 1, wherein the piezoelectric film has a thickness between 8 mm and 120 mm.
- 20 15. The apparatus of claim 1, further includes an electrical insulator between the piezoelectric film and the strap.
16. The apparatus of claim 1, wherein the pressure signals are indication of acoustic pressures propagating within the pipe.
- 25 17. The apparatus of claim 1, wherein the parameter of the fluid is one of steam quality or “wetness”, vapor/mass ratio, liquid/solid ratio, volumetric flow rate, mass flow rate, size of suspended particles, density, gas volume fraction, and enthalpy of the flow.

18. The apparatus of claim 1, wherein the signal processor determines the slope of an acoustic ridge in the k-w plane to determine a parameter of the process flow flowing in the pipe.
- 5 19. The apparatus of claim 1, wherein the pressure signals are indication of vortical disturbances within the fluid flow.
20. The apparatus of claim 19, wherein the parameter of the fluid is one of velocity of the process flow and the volumetric flow of the process fluid.
- 10 21. The apparatus of claim 1, wherein the signal processor determines the slope of a convective ridge in the k-w plane to determine the velocity of the fluid flowing in the pipe.
22. The apparatus of claim 1, wherein the signal processor determines the volumetric flow rate of the fluid flowing in the pipe in response to the velocity of the fluid.
- 15 23. The apparatus of claim 1, wherein the signal processor generates a flow velocity signal indicative of the velocity of the fluid flowing within the pipe by cross-correlating the pressure signals.
- 20 24. The apparatus of claim 1 wherein each sensor measures an acoustic pressure and provides a signal indicative of an acoustic noise within the pipe.
- 25 25. The apparatus of claim 1 further comprising at least three of said pressure sensors.
26. The apparatus of claim 1, wherein the pressure sensors are mounted to the outer surface of the pipe.
27. The apparatus of claim 26, wherein the pressure sensors are mounted to the outer surface of the pipe by an adhesive.
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